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Grant Support from the National Science Foundation to Improve Undergraduate Education for All Students in Science and Mathematics, Engineering and Technology

Herbert Levitan
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The articles in this special issue of the *Journal of the National Collegiate Honors Council* focus on honors courses and programs that include science, mathematics and/or technology education in an innovative way. My objective is to describe a program offered by the National Science Foundation's (NSF) Division of Undergraduate Education that supports the development of such courses and programs. In addition, I will indicate several reasons why faculty associated with honors programs may be particularly well positioned to submit competitive proposals to this program, as well as particular challenges that proposals from honors programs may face.

Many of the current programs and leadership efforts of NSF's Division of Undergraduate Education (DUE) reflect the recommendations made in *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering and Technology* (NSF Publication 96-139), in the National Research Council report *From Analysis to Action: Undergraduate Education in Science, Mathematics, Engineering, and Technology* (NRC, 1996), and in the National Research Council Report *Transforming Undergraduate Education in Science, Mathematics, Engineering and Technology* (NRC, 1999). These reports and follow-on activities have had broad-based input from faculty from the relevant disciplines, presidents and other administrators at academic institutions, representatives from business and industry, students, and parents. These activities highlighted the importance of an undergraduate education in science and mathematics for students with diverse aspirations, including:

- Students majoring in science, mathematics, engineering and technology;
- Prospective pre-Kindergarten through grade 12 teachers;
- Students preparing for the technological workplace; and
- All students, as citizens in a society increasingly dependent upon science and technology.

CHARACTERISTICS OF NSF'S COURSE, CURRICULUM AND LABORATORY IMPROVEMENT PROGRAM

The Course, Curriculum, and Laboratory Improvement (CCLI) program seeks to improve the quality of science, mathematics, engineering, and technological education for all students, and it targets activities affecting learning environments, course content, curricula, and educational practices. The program has three tracks that emphasize, respectively, the development of new educational materials and practices for a national audience, the adaptation and implementation into an institution of previously developed exemplary materials and practices, and the national dissemination of exemplary materials and/or practices. Projects may address the needs of a single discipline or cut across disciplinary bounds.

TRACK 1: EDUCATIONAL MATERIALS DEVELOPMENT (CCLI-EMD)

The objective of the CCLI-EMD track is to support the development of educational materials that incorporate practices that are effective in improving learning of science, mathematics, engineering, or technology (SMET) by undergraduates with diverse backgrounds and career aspirations. Projects are expected to address national needs or opportunities in undergraduate SMET education and to produce innovative materials of a quality and significance appropriate for national distribution, adoption, adaptation, and implementation.

The CCLI-EMD track invites two types of proposals that aim to achieve these goals: a) those that intend to establish a "proof of concept" or a prototype that would be responsive to a national need, and b) those that intend to fully develop a product or practice for national dissemination.

PROOF OF CONCEPT

A "proof of concept" project is expected to demonstrate the scientific and the educational feasibility of an idea. If development of the prototype proves successful, the project would be expected to move to full-scale development of the materials. Such a proposal for full development could be submitted to NSF for peer review and possible funding, or to other sources of potential support.

The outcomes expected of a CCLI-EMD Proof-of-Concept project include all of the following:

- A prototype that addresses a nationally recognized need and is based upon sound, effective pedagogy;
- A pilot test that provides a credible evaluation of the prototype; and
- Dissemination to the professional community about the prototype, and the results of the evaluation.

FULL DEVELOPMENT

A full development project is expected to produce and evaluate significant new educational materials and pedagogical practices, and to promote their dissemination and effective implementation nationally. The outcomes expected of the funded projects include all of the following:

- The full development of innovative materials that incorporate effective teaching and learning strategies and that are based upon prior experience with a prototype;
- A credible evaluation of the effectiveness of the materials or practices at different types of institutions serving students with diverse backgrounds and career goals;
- Preparation of faculty at test sites and other potential users to use the materials or practice;
- Dissemination of information about the developed materials; and
- Commercial or other self-sustaining national distribution (for

example, distribution through a commercial publisher or discipline-based professional society).

TRACK 2: ADAPTATION & IMPLEMENTATION (CCLI-A&I)

This track promotes the improvement of SMET education in the funded institution through adaptation and implementation of specific exemplary materials, laboratory experiences, or educational practices that have been developed and tested at other institutions. CCLI-A&I projects should effect change within or across departments or other institutional units by having broad faculty and administrative support.

Projects to adapt and implement high quality SMET curricula, materials, and/or techniques might include, for example:

- The incorporation of laboratory experiments or field experiences that effectively engage students in scientific processes and exploration of scientific concepts;
- The adaptation and testing of exemplary materials for use by a student audience significantly different from the one for which they were originally developed;
- The enhancement of teaching and learning through the use of resources, particularly instructional and information technologies, demonstrated to be of high quality;
- The development and use of collaborative learning, learning communities, and other innovations that aim to improve pedagogy in courses; or
- The integration of the study of pedagogy and content in science and mathematics core courses for prospective preK-12 teachers.

The scope of a project may range from an individual course or laboratory to a more comprehensive effort that impacts entire curricula or programs. The funds may be requested in any budget category normally supported by NSF or may be entirely for instrumentation.

Proposers of CCLI-A&I projects are expected to adapt and implement high-quality materials and effective educational practices developed elsewhere by individuals supported by NSF or by others. Adaptations that integrate significant advances from the research field into the undergraduate curriculum are also appropriate. Materials for adaptation may be drawn from more than one source.

Information about the results of projects funded through the Department of Undergraduate Education (DUE) programs can be obtained via the DUE Project Information Resource System http://www.ehr.nsf.gov/PIRSWeb/Search/. Many of these previously funded projects are in progress, and proposers may wish to contact the principal investigators for further information.

The outcomes expected of funded A&I projects include all of the following:

- Adaptation and implementation of exemplary practices and/or materials for course, curriculum, or laboratory improvements in innovative ways;
- An evaluation that informs the institution and others of the effectiveness of the implemented materials and practices, and also informs development of the project;
- Faculty professional development as needed in support of curricular adaptation and implementation;
- Efforts to build on the project and to broaden its impact at the institution, within the discipline or across disciplines; and
- Effective dissemination of project results to the broader community.

TRACK 3: NATIONAL DISSEMINATION (CCLI-ND)

This track supports the national dissemination of exemplary materials and practices by providing faculty with professional development activities. Eligible activities are not restricted to the dissemination of results from NSF-funded projects. Projects are invited from organizations that propose to provide faculty professional development opportunities on a national scale. Such organizations should be able to provide efficient administrative support to manage the logistics of these activities at multiple sites. Although it is expected that the primary mechanisms will be workshops, short courses, and distance learning opportunities, other means of dissemination are also encouraged.

These professional development opportunities are expected to enable faculty to introduce new content into undergraduate courses and laboratories, and to explore effective educational practices, thereby improving the effectiveness of their teaching. The new content may be scientific and technical knowledge, laboratory practices, or reformatted and synthesized content that supports new modes of learning. It is expected that the format will provide interaction with experts at a level deep enough to promote and achieve significant gains by participating faculty.

Successful proposals must aim to provide faculty professional development in a variety of disciplines or broadly within one of the following disciplines: behavioral sciences; biological sciences; chemistry; computer and information sciences; engineering; earth sciences; mathematical sciences; physics and astronomy; social sciences.

The outcomes expected of funded CCLI-ND projects include all of the following:

- Sets of materials for use by attending faculty that are appropriate for their needs;
- Participation by faculty representative of the national demographic and institutional diversity within the included disciplines;
- Follow-up activities to sustain faculty who participated in the professional development activities;
- A network of faculty actively using the disseminated best practices in their courses and classrooms;
- Evaluation protocols to assess the effectiveness of professional development activities and to improve their effectiveness.

Proposals submitted to each track should clearly indicate in the main body of the proposal how the objectives of the proposed project correspond to the outcomes expected, and describe in detail the plans to achieve these objectives and outcomes.

Consider, for example, the expected outcome that projects evaluate the impact of the effort on student learning. The objective is to determine what difference NSF's investment and the Principal Investigator's (PI) efforts have made. In spite of faculty familiarity with testing students to determine the students' level of achievement, faculty often have difficulty presenting a credible plan to determine how well they have succeeded in achieving the learning objectives they have set. A deficiency common to many assessment plans is that the project's objectives have not been defined with sufficient specificity. Skilled evaluators brought into the project from the start can be of great assistance in this respect. Individuals trained in assessment can and should be consulted to help with this task, and the cost of their time may be included in the budget for the project. In addition, there is a rich literature and other resources on assessment that can and should be consulted (see references below).

However, it may also be appropriate for prospective principal investigators to learn to design credible assessment schemes on their own, without becoming experts in assessment. For example, a PI could describe his/her project's learning objectives in terms of the knowledge and skills students should acquire by the end of the experience. An assessment plan would include the various ways in which students could demonstrate to an independent, objective observer that they have acquired these skills and knowledge. This would not include self-reported satisfaction of the outcomes by either students or the PI. To demonstrate that progress had been achieved as a result of the experiences and opportunities provided by the project, the students' knowledge and skills could be assessed before and after they engaged in the project. Indicators of success or progress toward success could include a demonstration that students are able to do things with the knowledge and skills they have acquired that they couldn't do before. An example might be to determine a student's ability to create an "ideal" exam question on a relevant topic, and to constructively critique a colleague's response to the exam question.

THE HONORS "ADVANTAGE" AND CHALLENGES

Proposals from honors programs may be stereotyped by reviewers, and while such expectations and stereotyping of students and faculty associated with honors may bestow some advantages, they also pose unique challenges. An applicant should be aware of and be prepared to address both the advantages and the challenges. Just as faculty teaching honors classes may have stereotypical expectations of the students enrolled, reviewers may expect projects associated with honors programs to be more likely to succeed because of the attributes of the faculty and students associated with them and because of the special status they have within an institution. Some of these attributes are real advantages, others are burdens.

Some of the reasons why the honors community might be in an especially good position to submit a competitive proposal to the CCLI program include:

- Experience in using the environment as resource (one example is the NCHC's perennial use of City as Text©; others include science-rich institutions in an urban area or the natural resources in any area);
- Incorporating students as collaborators, partners and even leaders of course or program-related activities;
- Forming alliances and partnerships with non-academic resources, such as people from the surrounding community in industry, business, community service organizations and local government;
- Attracting students with diverse interests and aspirations, who are capable and competent in science and mathematics but may not be majoring in science, to engage in interdisciplinary studies;
- Incorporating multicultural perspectives by making explicit use of the diverse backgrounds and experiences of students in the honors program;
- Using writing, or more generally communication, as a means to learn science and mathematics;
- Teaching to learn by engaging students as teaching assistants and peer tutors;
- Learning communities which engage faculty from different disciplines in cooperative ventures;
- Experimenting with innovative styles of learning and giving students responsibility for their own learning;
- Readily available venues for communicating/disseminating experiences, such as JNCHC and the NCHC national meeting.

Although faculty associated with honors programs may have some competitive advantages, they also face distinct challenges.

It is often assumed that honors programs are given special resources to accomplish their goals, which might not be available to others. For example, it may be assumed that honors programs have the best or at least the most highly motivated students, that their student-faculty ratio is low, and that they have access to special resources such as space, scholarships, resource people and equipment. Thus reviewers express skepticism about the generalizability of honors projects to the broader population, where the needs, numbers, problems and opportunities are greater.

Thus, applicants need to address in detail:

- the generalizability of their projects to students and faculty not associated with honors programs, and their institution's commitment to extending what is learned beyond the honors community;
- how the innovations that are successful will be sustained and institutionalized;
- how they will credibly assess the impact of the innovations introduced on student learning.

These challenges and others might be directly addressed if projects conceived by honors programs include on their planning teams and as their test sites those who are not members of the honors community.

In addition to serving as a principal investigator on a project, faculty and administrators with science and mathematics backgrounds can contribute to the improvement of undergraduate education for all students in the sciences by serving as a member of a team on a project conceived by others, being a member of a coalition or consortium, serving on an advisory board for a funded project, or serving as a beta tester of materials and methods developed by others. Faculty can also serve as reviewers of proposals submitted to the CCLI program, and can make their interest in doing this known by filling out and submitting NSF Form 428A, which is available on the Web at http://www.nsf.gov/cgi-bin/getpub?form428a. This form should be mailed to DUE along with a resume, or the information e-mailed to "undergrad@nsf.gov."

Disclaimer: The views expressed in this article are those of the author, and do not necessarily reflect those of the National Science Foundation.

REFERENCES

1 Website for the NSF's Division of Undergraduate Education for Program Announcement of Course, Curriculum and Laboratory Improvement program and supplement to the announcement NSF 00-117: Supplemental Information for Principal Investigators and Applicants to NSF's Course, Curriculum, and Laboratory Improvement Program, http://www.ehr.nsf.gov/ehr/due/default.asp;

2 *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology* (NSF Publication 96-139), http://www.ehr.nsf.gov/ehr/due/outreach/stf/publications.asp

3 *From Analysis to Action: Undergraduate Education in Science, Mathematics, Engineering, and Technology*. National Research Council Report (1996), http://www.nap.edu/catalog/9128.html.

4 *Transforming Undergraduate Education in Science, Mathematics, Engineering and Technology*. National Research Council Report (1999), http://www.nap.edu/catalog/6453.html.\

The following references may be helpful in designing an evaluation plan:

- *User Friendly Handbook for Project Evaluation: Science, Mathematics, Engineering and Technology Education* (NSF 93-152, revised 2/96). See: http://www.ehr.nsf.gov/EHR/RED/EVAL/Handbook/handbook.htm
- *User Friendly Handbook for Mixed Method Evaluations* (NSF 97-153). See: http://www.ehr.nsf.gov/EHR/REC/pubs/NSF97-153/start.htm
- Online Evaluation Resource Library. See http://oerl.sri.com.
- *Field-tested Learning Assessment Guide* (FLAG). See: http://www.wcer.wisc.edu/nise/CL1/flag/

Herbert Levitan may be contacted individually at:

Herbert Levitan
Program Director
Division of Undergraduate Education
Directorate for Education and Human Resources
National Science Foundation
4201 Wilson Boulevard, Room 835
Arlington, VA 22230
hlevitan@nsf.gov